CLAIMS

1. An apparatus for controlling the flow of a gas mixture of variable proportions, the apparatus comprising

a conduit for the flow of gas;

a delivery means for delivery to the conduit of a gas mixture having gaseous components in controlled variable proportions;

a regulator for regulating the flow of gas through the conduit;

a driver for operating the regulator;

a setpoint signal generator for generating a setpoint signal according to a desired setpoint;

a volumetric flow meter situated downstream of the valve;

a feedback signal generator associated with the volumetric flow meter, said feedback signal corresponding to the flow rate measured by the volumetric flow meter; and

an adjustment signal generator for generating an adjustment signal for controlling the driver by which the regulator is operated to open or close by an amount corresponding to the adjustment signal to achieve a desired flow rate corresponding to the desired setpoint, which adjustment signal generator comprises a comparator for comparing the setpoint signal and the feedback signal.

2. An apparatus for correcting the flow of a gas mixture of variable proportions through a conduit, which flow is regulated by a regulator operated by a driver in response

to a setpoint signal generated, from a desired setpoint corresponding to a desired gas flow rate, by a setpoint signal generator which is connected to said driver, said apparatus comprising

a volumetric flow meter for measuring the rate of flow of gas through the conduit downstream of the regulator;

a feedback signal generator associated with the volumetric flow meter, said feedback signal generator being arranged to generate a feedback signal corresponding to the flow rate measured by the volumetric flow meter; and

a comparator for generating an adjustment signal for correcting the rate of flow,

wherein the setpoint signal generator is connected to the driver via the comparator in which the setpoint signal is compared with the feedback signal and the setpoint is corrected by reference to the feedback signal to produce an adjustment signal for transmission to the driver to adjust the regulator to cause a change in the rate of flow of gas therethrough thereby reducing any discrepancy between the desired gas flow rate and the measured gas flow rate.

3. Apparatus according to claim 1, wherein the setpoint signal generator is hard wired to the driver via a comparator.

4. Apparatus according to any one of claims 1 to 3, further comprising a gas mixture which is a gaseous composition comprising variable amounts of at least two gaseous components having different molar specific heat capacities.

5. Apparatus according to claim 4, wherein the gaseous composition comprises xenon in admixture with oxygen and/or nitrogen.

6. Apparatus according to any one of claims 1 to 5, wherein the volumetric flow meter is one of a turbine wheel flow meter, a positive displacement meter, a near-positive displacement meter, a vortex shedding meter, a swirl plate turbine meter and a correlation flow meter.

7. Apparatus according to claim 6, wherein the turbine wheel flow meter is a Pelton wheel flow meter.

8. Apparatus according to any one of claims 1 to 7, wherein the setpoint signal generator comprises a potentiometer upon which may be set the desired setpoint corresponding to a desired flow rate through the conduit.

9. Apparatus according to any one of claims 1 to 8, wherein the setpoint signal generator comprises a slowdown circuit such that the setpoint signal increases or decreases over time until the setpoint signal corresponding with the desired setpoint is reached.

10. Apparatus according to claim 9, wherein the slowdown circuit comprises a resistor in series with the potentiometer and a capacitor in parallel with the potentiometer.

11. Apparatus according to claim 10, wherein the time over which the setpoint signal increases or decreases in response to a change in desired setpoint is a function of the resistance, the capacitance and the voltage applied across the capacitor.

12. Apparatus according to claim 10 or 11, wherein the time over which the slowdown circuit increases or decreases

setpoint signal is such that it compensates for the inherent delayed response time of the volumetric flow meter to changes in the rate of flow through the conduit.

13. Apparatus according to any one of claims 10 to 12, wherein the setpoint signal generator comprises a potentiometer variable between 0 V and 5 V corresponding to a flow rate through the conduit of 0 l/min and 10 l/min, a resistor having a resistance of about 330 kΩ and a capacitor having a capacitance of about 40 μF.

14. Apparatus according to any one of the preceding claims, wherein the regulator is a proportional solenoid valve.

15. Apparatus according to claim 14, wherein the driver has an AC component in its output with a frequency of from 150 Hz to 400 Hz.

16. Apparatus for providing and circulating a gaseous composition to a medical device, said apparatus comprising:-

a main circuit for recirculatory flow of gas to and from said medical device;

a gas source for providing gas to the main circuit; and

an apparatus for controlling the flow of gas according to any one of Claims 1 and 3 to 15, for controlling the flow of gas to the medical device and/or from the gas source to the main circuit.

17. Apparatus according to claim 16, wherein the gaseous composition comprises a first gas and a second gas.

18. Apparatus as claimed in claim 17, wherein the main circuit comprises a circulation pump for pumping gas through the circuit to supply the medical device with a gas composition comprising a first gas and a second gas,

a gas outlet for connection to the medical device to supply gas thereto,

a gas inlet for connection to the medical device to receive spent gas therefrom,

a first supply conduit for supply of gas of a first composition from a first gas source to the circuit,

a second supply conduit for supply of gas of a second composition different from said first composition from a second gas source to the circuit,

a first supply flow controller for controlling the flow of gas through the first supply conduit, and

a second supply flow controller for controlling the flow of gas through the second supply conduit;

and which apparatus further comprises

a concentration determiner for determining the concentration of at least one gas in the gaseous composition within the circuit; and

a vent for venting gas from the circuit.

19. Apparatus according to claim 18, which further comprises a bypass circuit, which permits at least a portion of the recirculating gas to bypass the gas outlet and the gas inlet, a gas outlet flow controller for controlling the flow of gas through the gas outlet and a pressure maintainer for maintaining the pressure to the gas outlet by controlling the flow of gas through the bypass conduit whereby flow of gas through the bypass conduit is prevented unless a predetermined pressure is attained.

20. Apparatus according to claim 19, which further comprises a circuit volume regulator for taking up temporary increases in recirculating gas volume and compensating for temporary decreases in recirculating gas volume.

21. Apparatus according to claim 20, wherein the circuit volume regulator comprises expansion bellows.

22. Apparatus according to claim 20 or claim 21, which further comprises a monitor for monitoring the relative increases and decreases in gas volume in the circuit according to the circuit volume regulator.

23. Apparatus according to any one of claims 18 to 22 comprising

a first circuit gas concentration controller, including the first supply flow controller, for controlling the concentration of the first gas in the gaseous composition, which first circuit gas concentration controller comprises a first gas concentration determiner for determining the concentration of the first gas in the gaseous composition and communicating with the first supply flow controller for controlling flow of the first gas through the first supply conduit; and

a second circuit gas concentration controller, including the second supply flow controller, for controlling the concentration of the second gas in the gaseous composition, which second circuit gas concentration controller comprises a second gas concentration determiner for determining the concentration of the second gas in the gaseous composition and communicating with the second supply flow controller for controlling flow of the second gas through the second supply conduit,

whereby on reaching a respective predetermined level, each of said determiners triggers the corresponding flow controller to increase the flow of the corresponding gas to the circuit.

24. Apparatus according to claim 23, wherein the first circuit gas concentration controller comprises a first gas concentration determiner for determining the concentration of the first gas in the gaseous composition and communicating with the first supply flow controller for controlling flow of the first gas through the first supply conduit and the second circuit gas concentration controller comprises a monitor for monitoring the relative increases and decreases in gas volume in the circuit and communicating with the second supply flow controller for controlling flow of the second gas through the second supply conduit, whereby on reaching a respective predetermined level, each of said determiners and said monitor triggers the corresponding flow controller to increase the flow of the corresponding gas to the circuit.

25. Apparatus according to claim 23 or claim 24, wherein the first circuit gas concentration controller comprises a relatively high gain analog electrical circuit and the second circuit gas concentration controller comprises a relatively low gain analog electrical circuit, whereby the increase in flow rate of the first gas is relatively quick and the increase in flow rate of the second gas is relatively slow.

26. Apparatus according to any one of claims 16 to 25, which further comprises an ultrasonic xenon analyser.

27. Apparatus according to any one of claims 16 to 26, comprising a gas recovery space and a vent for feeding recirculating gas to said space.

28. Apparatus according to claim 27, wherein the gas recovery space is an ullage space of a container providing said first composition.

29. Apparatus comprising:-

a medical device requiring a supply of a gaseous composition comprising a first gas and a second gas;

a main circuit for recirculating gas through the medical device and comprising:-

a circulation pump for pumping gas through the main circuit,

a gas outlet connected to the medical device,

a gas inlet connected to the medical device,

a first supply conduit for supply of gas of a first composition to the main circuit,

a second supply conduit for supply of gas of a second composition different from said first composition to the main circuit,

a gas outlet flow controller for controlling the flow of gas to the medical device;

a first supply flow controller for controlling the flow of gas through the first supply conduit; and

a second supply flow controller for controlling the flow of gas through the second supply conduit;

a concentration determiner for determining the concentration of at least one gas of the gaseous composition within the main circuit; and

a vent for venting gas from the main circuit,

wherein at least one of the gas outlet flow controller, the first supply flow controller and the second supply flow controller comprises a regulator, a setpoint signal generator and a volumetric feedback correction system.

30. An apparatus according to claim 29, wherein the setpoint signal generator is hard-wired to the regulator.

31. Apparatus according to claim 29 or 30, wherein at least one of the gas outlet flow controller, the first supply flow controller and the second supply flow controller comprises an apparatus for controlling the flow of gas according to any of claims 1 and 3 to 13.

32. Apparatus according to claim 31, which further comprises a pressure maintainer for maintaining the pressure to the gas outlet by controlling the flow of gas through the bypass conduit whereby flow of gas through the bypass conduit is prevented unless a predetermined pressure is attained.

33. Apparatus according to claim 31 or 32, which further comprises a circuit volume regulator for taking up temporary increases in recirculating gas volume and compensating for temporary decreases in recirculating gas volume.

34. Apparatus according to claim 33, which further comprises a monitor for monitoring the relative increases and decreases in gas volume in the circuit according to the circuit volume regulator.

35. Apparatus according to any one of claims 29 to 34, which further comprises:-

a first circuit gas concentration controller, including the first supply flow controller, for controlling the concentration of the first gas in the gaseous composition, which first circuit gas concentration controller comprises a first gas concentration determiner for determining the concentration of the first gas in the

gaseous composition and communicating with the first supply flow controller for controlling flow of the first gas through the first supply conduit; and

a second circuit gas concentration controller, including the second supply flow controller, for controlling the concentration of the second gas in the gaseous composition, which second circuit gas concentration controller comprises a second gas concentration determiner for determining the concentration of the second gas in the gaseous composition and communicating with the second supply flow controller for controlling flow of the second gas through the second supply conduit,

whereby on reaching a respective predetermined level, each of said determiners triggers the corresponding flow controller to increase the flow of the corresponding gas to the circuit.

36. Apparatus according to claim 35, wherein the first circuit gas concentration controller comprises a first gas concentration determiner for determining the concentration of the first gas in the gaseous composition and communicating with the first supply flow controller for controlling flow of the first gas through the first supply conduit and the second circuit gas concentration controller comprises a monitor for monitoring the relative increases and decreases in gas volume in the circuit and communicating with the second supply flow controller for controlling flow of the second gas through the second supply conduit, whereby on reaching a respective predetermined level, each of said determiner and said monitor triggers the corresponding flow controller to increase the flow of the corresponding gas to the circuit.

37. Apparatus according to claim 35 or 36, wherein the first circuit gas concentration controller comprises a

high gain analog electrical circuit and the second circuit gas concentration controller comprises a relatively low gain analog electrical circuit, whereby the increase in flow rate of the first gas is relatively quick and the increase in flow rate of the second gas is relatively slow.

38. Apparatus according to any one of claims 29 to 37, which further comprises an ultrasonic xenon analyser.

39. Apparatus according to any one of claims 29 to 38, comprising a gas recovery space and a vent for feeding recirculating gas to said space.

40. Apparatus according to claim 39, wherein the gas recovery space is an ullage space of a container providing said first composition.

41. Apparatus according to any one of claims 29 to 40, wherein the medical device is selected from a cardiopulmonary bypass oxygenator and an artificial ventilator.

42. Apparatus according to claim 41, wherein the medical device is a cardiopulmonary bypass oxygenator.

43. Apparatus according to claim 42, which apparatus further comprises one or more of a carbon dioxide absorber, a carbon dioxide analyser and a pressure relief device downstream from the oxygenator.

44. A method of controlling the flow of a gas mixture of variable proportions through a conduit having a regulator located therein against which is provided a known pressure of the gas mixture, said method comprising:

adjusting a setpoint on a potentiometer to a desired setpoint from a previous setpoint, which potentiometer is

connected to a driver for operating the regulator, said desired setpoint corresponding to a desired flow of fluid through the conduit as controlled by the regulator;

generating a setpoint signal from the adjusted desired setpoint on the potentiometer;

measuring the rate of flow of fluid passing through the conduit using a volumetric flow meter downstream from the regulator;

generating a feedback signal from the volumetric flow meter;

comparing the feedback signal with the setpoint signal;

generating an adjustment signal corresponding to the discrepancy between the setpoint signal and the feedback signal; and,

adjusting the regulator, using the driver, by an amount corresponding to the adjustment signal.

45. A method according to claim 44, wherein the potentiometer is hard-wired to the driver and the feedback signal and the setpoint signal are compared using hard-wired electronics apparatus.

46. A method according to claim 45, wherein the feedback signal and the setpoint signal are compared using an operational amplifier.

47. A method according to any one of claims 44 to 46, which further comprises increasing or decreasing the setpoint signal over a time period and by an amount

corresponding to the difference between the desired setpoint and the previous setpoint.

48. A method according to claim 47, in which the time period is of an amount to compensate for the delay in generating a feedback signal from the volumetric flow meter which accurately reflects the actual volume of gas passing through the conduit, which delay is caused by the response time of the volumetric flow meter.

49. A method according to claim 47 or claim 48, wherein increase or decrease in the setpoint signal over a time period is effected by providing a means of automatically adjusting the setpoint signal over the time period in response to a desired setpoint.

50. A method according to claim 49, wherein the means of automatically adjusting the setpoint signal is a resistor and capacitor arrangement in which the resistor is arranged in series with the potentiometer and the capacitor is arranged in parallel with the potentiometer.

51. A method according to any one of claims 47 to 50, in which the time delay compensates for a response time of the volumetric flow meter such that the rate of flow of fluid through the conduit is relatively smoothly adjusted from a rate corresponding to the previous setpoint to a rate corresponding to the desired setpoint.

52. A method of providing a medical device with a gaseous composition comprising a first gas and a second gas in controlled variable proportions, said method comprising:-

controlling the flow of a gaseous composition of a desired composition through a conduit leading to the medical device, said conduit having a regulator located

therein which regulator, when closed is subject to a gas pressure of at least a desired level, by

adjusting a setpoint on a potentiometer to a desired setpoint from a previous setpoint, which potentiometer is connected to a driver for operating the regulator, said desired setpoint corresponding to a desired flow of fluid through the conduit as controlled by the regulator;

generating a setpoint signal from the adjusted desired setpoint on the potentiometer;

measuring the rate of flow of fluid passing through the conduit using a volumetric flow meter downstream from the regulator;

generating a feedback signal from the volumetric flow meter;

comparing the feedback signal with the setpoint signal;

generating an adjustment signal corresponding to the discrepancy between the setpoint signal and the feedback signal; and

adjusting the regulator, using the driver, by an amount corresponding to the adjustment signal;

collecting spent gas mixture from the device;

determining the concentration of each of the components of the gaseous composition remaining in the spent gas mixture;

processing the spent gas mixture to remove unwanted components;

replenishing components in the spent gas mixture in response to the concentration determination to regenerate said desired composition; and

recirculating resultant gaseous composition to the medical device.

53. A method according to claim 52, which further comprises providing means of automatically increasing or decreasing the setpoint signal over a time period and by an amount corresponding to the difference between the desired setpoint and the previous setpoint, which time period is of an amount to compensate for the delay in generating a feedback signal from the volumetric flow meter which accurately reflects the real-time volume of gas passing through the conduit, which delay is caused by the response time of the volumetric flow meter.

54. A method according to claim 53, wherein the means of automatically adjusting the setpoint signal is a resistor and capacitor arrangement in which the resistor is arranged in series with the potentiometer and the capacitor is arranged in parallel with the potentiometer.

55. A method according to any one of claims 52 to 54, which further comprises replenishing components in the spent gas mixture in response to the concentration determination to generate a new desired composition.

56. A method according to claim 55, which further comprises maintaining the pressure of the gaseous composition being fed into the medical device at a desired level by diverting a portion of the gaseous composition to

bypass the medical device when the desired pressure is exceeded.

57. A method according to any on of claims 52 to 56, which further comprises removing and storing spent gas for subsequent recovery in response to the concentration of an active component falling below a predetermined level or the concentration of an unwanted component exceeding a predetermined level.

58. A method according to any one of claims 52 to 57, wherein the medical device is a cardiopulmonary bypass oxygenator or an artificial ventilator.

59. A method according to any one of claims 52 to 58, wherein the first gas is oxygen and the second gas comprises xenon.

60. A method according to claim 59, wherein the second gas is a mixture of xenon and oxygen in the ratio of about 80% to about 20% by volume.

61. A method for the extracorporeal treatment of blood by contacting blood with a recirculating gaseous composition in a device provided with a gaseous composition using a method defined in any one of claims 52 to 60.

62. Use of a volumetric flow meter to provide feedback correction to a regulator in a flow control apparatus for controlling the flow of a gas mixture of variable proportions of gaseous components through a conduit.

63. A use according to claim 62, wherein the volumetric flow meter is a turbine wheel flow meter.

64. A method of providing a medical device with a gaseous composition comprising xenon and oxygen in controlled variable proportions, said method comprising:-

controlling the flow of a gaseous composition of a desired composition through a conduit leading to the medical device, said conduit having a regulator located therein which regulator, when closed is subject to a gas pressure of at least a desired level, by

adjusting a setpoint on a potentiometer to a desired setpoint from a previous setpoint, which potentiometer is connected to a driver for operating the regulator, said desired setpoint corresponding to a desired flow of fluid through the conduit as controlled by the regulator;

generating a setpoint signal from the adjusted desired setpoint on the potentiometer;

measuring the rate of flow of fluid passing through the conduit using a volumetric flow meter downstream from the regulator;

generating a feedback signal from the volumetric flow meter and using said feedback signal to control the regulator.

65. A method according to claim 64, in which using the feedback signal to control regulator comprises:-

comparing the feedback signal with the setpoint signal;

generating an adjustment signal corresponding to the discrepancy between the setpoint signal and the feedback signal; and

adjusting the regulator, using the driver, by an amount corresponding to the adjustment signal;

66. An apparatus for controlling the rate of flow of gas through a conduit, said apparatus comprising:

a flow regulator for regulating the rate of flow of gas through a conduit;

a digital potentiometer for providing a controllable output signal for controlling the flow regulator to provide a selected flow rate of gas;

a first digital encoder, which is a rotary encoder, having an output for selectively increasing and decreasing the resistance of the potentiometer; and

at least one other digital encoder having an output for selectively increasing and decreasing the resistance of the potentiometer,

the arrangement being such that the voltage of the output signal from the digital potentiometer can be selectively increased and decreased by independent manipulation of the first digital encoder and the at least one other digital encoder thereby enabling independent control of the rate of flow of gas through the conduit from more than one location.

67. An apparatus according to claim 66, wherein the at least one other digital encoder is a rotary encoder.

68. An apparatus according to claim 66 or claim 67, comprising isolating devices connected to the outputs of each of the digital encoders.

69. An apparatus according to claim 68, wherein each isolating device comprises an isolating capacitor and a resistor connected in parallel.

70. An apparatus according to claim 66 or 67, wherein the digital potentiometer comprises an increment input for receiving signals from a first output of each of the digital encoders, and an up input and a down input for receiving signals from a second output of each of the digital encoders, and further comprising isolating devices connected to each of the first and second outputs of the digital encoders.

71. An apparatus according to claim 70, wherein each isolating device comprises an isolating capacitor and a resistor connected in parallel.

72. An apparatus according to claim 70 or 71, wherein the up input and down input of each digital potentiometer are in the form of a single U/Dbar input.

73. An apparatus according to any one of claims 70 to 72, wherein a first isolating device is connected to the first outputs of the digital encoders and a second isolating device is connected to the second outputs of the digital encoders.

74. An apparatus according to any one of claims 66 to 73, wherein the control circuit comprises only two digital encoders.

75. An apparatus according to any one of claims 66 to 74, which further comprises a delivery means for delivery to the conduit of a gas mixture having gaseous components in controlled variable proportions, whereby the flow of a gas mixture of variable proportions through the conduit can be controlled independently from a plurality of locations.